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Dairy Report

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Lactation Curves for Milk, Fat and Protein Yields and Somatic Cell Scores of Holstein Cows Treated With Bovine Somatotropin

Bruce DeGroot
Jeffrey F. Keown[1]

Summary

The objective was to estimate lactation curves for cows treated or not treated with bovine somatotropin (bST) from test-day milk, fat and protein yields and SCS. Test-day records of Holstein cows that calved in 1994 through early 1999 were obtained from Dairy Records Management Systems in Raleigh, N.C., for the analysis. The test-day model included herd test-day, age at first calving, and bST vs. no bST treatment as fixed effects. Cubic spline functions were used to fit the overall lactation curve, additive genetic effects and permanent environmental effects. Estimates of (co)variances were obtained with REML. Overall lactation curves were plotted for bST and non-bST-treated cows from estimates obtained from the REML analysis. Differences between bST-treated and untreated cows were 2 to 4 kg and 0.10 to 0.16 kg for test-day milk and fat yields, respectively, with smaller differences for test-day protein yield at day 90 which were maintained until about day 305 of lactation. Differences due to bST treatment were smaller for test-day yields for lactations two and three than for lactation one. Small differences were estimated between bST-treated and untreated cows for test-day SCS for lactations one, two and three.

Introduction

Bovine somatotropin (bST) is a protein-based growth hormone that can be used to stimulate milk production in dairy cattle. In general, bST regulates the use of nutrients needed for growth and milk production. In commercial dairy herds, bST usually is administrated subcutaneously every two weeks after about the ninth week of lactation. Milk yield gradually increases the first few days after bST treatment and reaches a maximum about six days after administration. Currently, approximately 13,000 dairy producers use the product as reported by the Monsanto Co.

An early study reported increases of 20 to 40% in milk yield for dairy cows receiving bST treatment. A later study used a test-day model to examine response to bST in northeast commercial dairy herds from July 1994 to March 1998. That study reported responses to bST treatment of 6.46 lb. per day for milk yield and 0.194 and 0.221 lbs. per day for fat and protein yields, respectively. The study also reported that somatic cell counts were not different for bST-treated and not treated.

The objective of this study was to estimate for three lactations for milk, fat and protein yields and somatic cell scores for differences between Holstein cows treated or not treated with bST with a test-day model.

Procedures

Test-day yields of Holstein cows from Dairy Herd Improvement herds that calved from 1994 through early 1999 were obtained from Dairy Records Management Systems of Raleigh, N.C. Each cow was required to have at least a 305-day mature equivalent record with two times a day milking and to have at least eight test-day records. Records were deleted for any lactation if days in milk were less than 200 days or greater than 350 days, pedigree information on sire and dam was missing, lactation began with an abortion, or birth and calving data were missing. Each test-day record was coded whether or not the cow was treated with bST. Only herds in which at least half of the cows received bST treatment were included in the analysis. Cows were considered bST-treated if the bST treatment started no later than test-day 3 and bST treatments were coded for at least five consecutive test-days. Cows considered to be untreated were not allowed any codes for bST treatment during any part of the lactation.

A single trait test-day model with a cubic spline function was used to fit lactation curves and deviations for each animal for both

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random genetic and permanent environmental components. The fixed effects were bST code (0,1), herd-test-day, a covariate for age at the beginning of lactation, and a covariate for day in milk for each test-day record. Random effects included overall spline, animal genetic, permanent environmental and residual effects. The ASREML program was used for the analysis. From the results of the analysis, lactation curves for milk, fat, and protein yields and SCS were plotted for bST and non-bST-treated cows.

Results

Figures 1, 2 and 3 show the lactation curves for milk, fat and protein yields, respectively, for treated and untreated bST cows. The lactation curve for milk yield showed the typical rapid increase in production to about day 60 followed by a gradual decline. Fat and protein yields increased during the early stages of the lactation and then slowly decreased over the course of the lactation. The bST-treated cows showed a response in production at day 40 for milk and fat yields and at day 100 for protein yield. Producers may have administrated bST to some cows earlier than recommended or higher producing cows received bST treatments. Figure 4 shows lactation curves for treated and untreated bST cows for SCS. The curve indicates that SCS decreased from the beginning of lactation to about day 80, then slowly increased to the end of lactation. The bST-treated cows had slightly higher SCS than cows not treated with bST.

Estimates of differences between bST-treated and untreated cows for lactation one as calculated for the midpoints of 10 typical test-day intervals for milk, fat and protein yields and SCS are in Table 1. Estimates of differences between

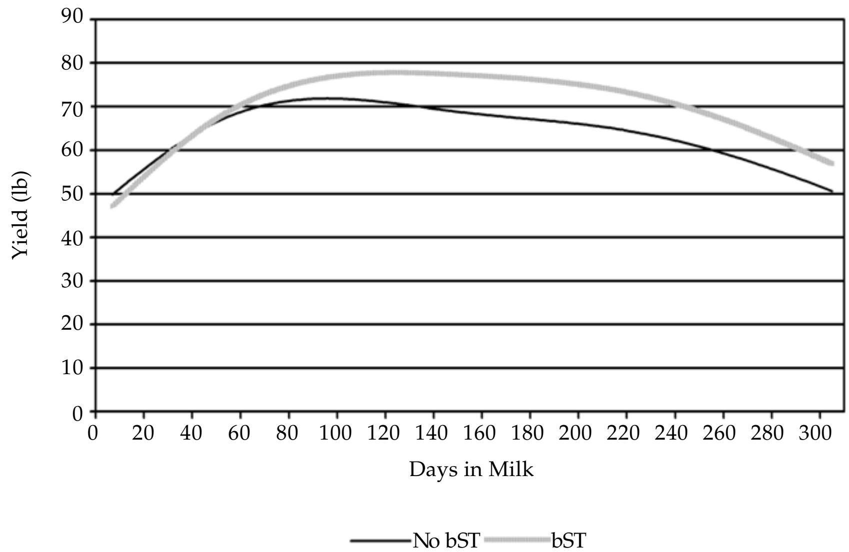


Figure 1. Lactation curves for milk yield for treated and untreated bST cows for lactation 1.

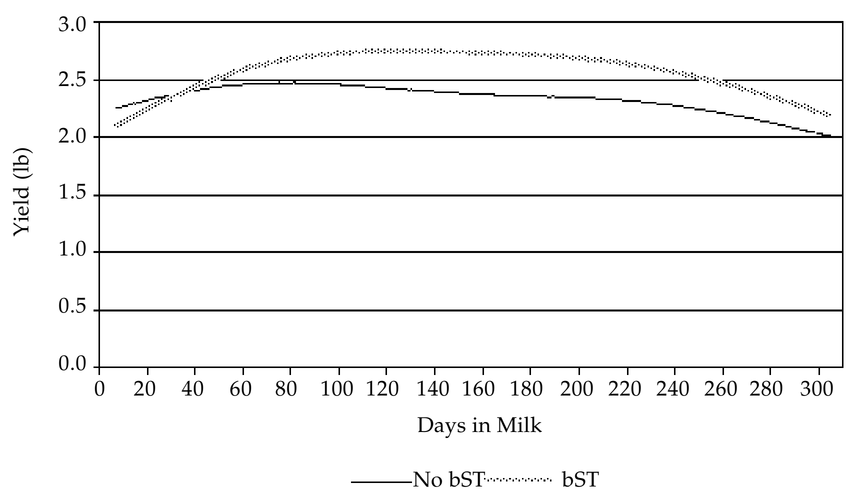
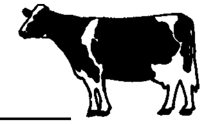


Figure 2. Lactation curves for fat yield for treated and untreated bST cows for lactation 1.

Table 1. Estimates of differences[a] for milk, fat, and protein yields (lb.) and SCS for treated bST and untreated cows for ten representative days in milk (DIM) for lactation 1.

Test	DIM	Milk yield	Fat yield	Protein yield	SCS
1	18	-1.87	-0.09	-0.07	-0.02
2	46	0.40	0.07	-0.07	0.05
3	76	3.09	0.20	-0.02	0.10
4	106	5.73	0.29	0.04	0.14
5	136	7.85	0.33	0.11	0.16
6	167	9.02	0.35	0.15	0.16
7	196	9.13	0.35	0.15	0.16
8	227	8.64	0.31	0.13	0.16
9	256	7.89	0.26	0.11	0.16
10	288	6.88	0.20	0.04	0.15

[a]bST estimates minus non-bST estimates.



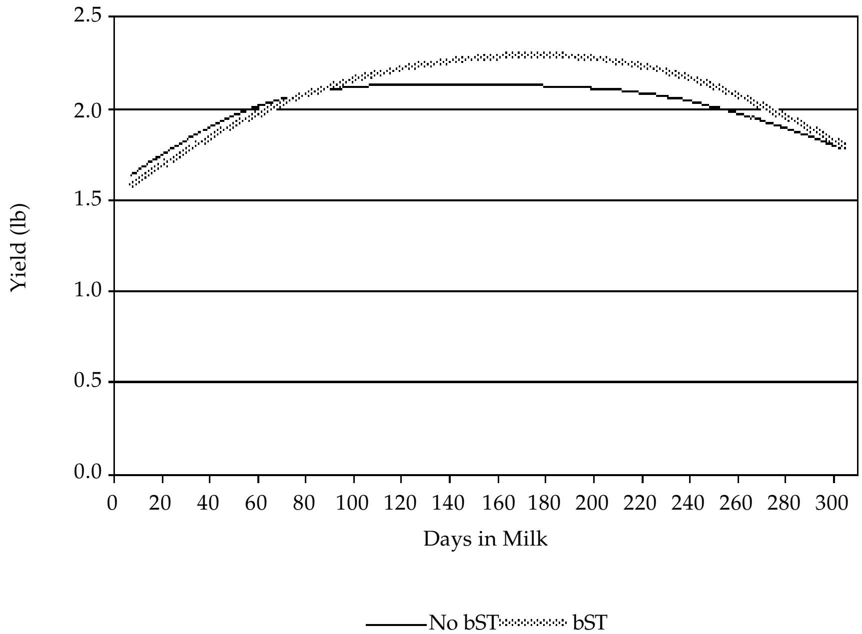


Figure 3. Lactation curves for protein yield for treated and untreated bST cows for lactation 1.

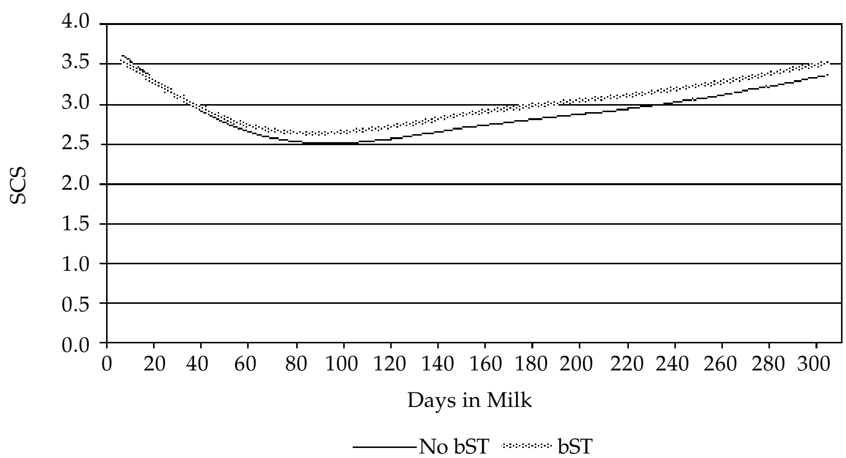


Figure 4. Lactation curves for SCS for treated and untreated bST cows for lactation 1.

Table 2. Estimates of differences[a] for milk, fat, and protein yields (lb.) and SCS for treated bST and untreated cows for ten representative days in milk (DIM) for lactation 2.

Test	DIM	Milk yield	Fat yield	Protein yield	SCS
1	18	-3.11	-0.11	-0.07	0.04
2	46	0.37	0.00	-0.11	0.06
3	76	3.48	0.13	-0.06	0.06
4	106	5.78	0.22	0.00	0.06
5	136	7.06	0.29	0.09	0.06
6	167	7.19	0.29	0.13	0.07
7	196	6.31	0.24	0.11	0.09
8	227	4.72	0.18	0.07	0.12
9	256	2.91	0.09	0.00	0.15
10	288	0.68	0.02	-0.07	0.20

[a]bST estimates minus non-bST estimates.

treated and untreated bST cows were from 3.09 to 9.13 lb., from day 76 to day 196. The difference decreased slightly towards the end of the lactation to about 6.88 lb. at day 288. Estimates of differences between untreated and treated cows for test-day fat yield were 0.20 to 0.35 lb. per day from day 76 to day 196. The difference decreased toward the end of the lactation to 0.20 lb. at day 288. Only small differences were estimated for protein yields: 0.04 to 0.15 lb. from day 106 to day 196. Differences decreased to 0.04 lb. at day 288. The differences between bST-treated and untreated cows were small for SCS. Estimates of differences were 0.05 to 0.15 SCS from day 46 to 256. These differences for milk, fat and protein yields and for SCS were similar to those that have been reported in earlier studies.

Estimates of differences between bST-treated and untreated cows for lactation two as calculated for the midpoints of 10 test-day intervals for milk, fat and protein yields and SCS are in Table 2. Estimates of differences between treated and untreated bST cows were from 3.48 to 6.31 lb. per day from day 76 to day 196. For fat yield differences between untreated and treated cows were 0.13 to 0.29 lb. per day from day 76 to day 167. Differences were small for protein yields from 0.09 to 0.13 lb. per day for day 136 to day 167. The relative responses to bST for milk, fat and protein yields for lactation two were less than those for lactation one. For SCS differences ranged from 0.06 to 0.20 from day 46 to day 256, which were less than differences for lactation one, except at the end of lactation two.

Estimates of differences between bST-treated and untreated cows for lactation three as calculated for the midpoints of 10 test-day intervals for milk, fat and, protein

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yields and SCS are in Table 3. Estimates of differences between treated and untreated cows were from 1.17 to 5.40 lb. per day from day 76 to day 167. Differences for milk yields were less than those for lactations one and two. For fat yield differences between untreated and treated cows were 0.18 to 0.26 lb. from day 76 to day 167. Differences for protein yields were 0.04 to 0.13 lb. for day 106 to day 167. Differences for fat and protein yields for lactation three were less than for lactation one and similar to differences for lactation two. Differences between bST-treated and untreated cows were small for SCS: 0.05 to 0.18 SCS for day 46 to day 288. The differences were similar to those for lactation two.

Table 3. Estimates of differences[a] for milk, fat, and protein yields (lb.) and SCS for treated bST and untreated cows for ten representative days in milk (DIM) for lactation 3.

Test	DIM	Milk yield	Fat yield	Protein yield	SCS
1	18	-2.27	-0.13	-0.07	0.01
2	46	-0.82	0.04	-0.07	0.05
3	76	1.17	0.18	-0.04	0.08
4	106	3.24	0.24	0.04	0.10
5	136	4.85	0.26	0.11	0.11
6	167	5.40	0.26	0.13	0.12
7	196	4.85	0.22	0.11	0.12
8	227	3.62	0.18	0.07	0.14
9	256	2.23	0.11	0.02	0.16
10	288	0.53	0.02	-0.04	0.18

[a]bST estimates minus non-bST estimates.

Conclusions

Yield traits showed a response to bST for all lactations. The response for milk yield in the first lactation was similar to responses reported in earlier studies from research and commercial herds. The response for milk yield to bST treatment was greater for lactation one than for lactations two and three. The decreased responses in lactation two and three may be due to culling. If low-producing cows were culled at the end of lactation one, the lower producing cows would not have later lactations, which might reduce the differences between bST-treated and untreated cows in later lactations.

The SCS are used as measures of quality of milk and of mammary health, especially of susceptibility to mastitis. If an infection occurs within the udder, SCS increases in the milk. Increased milk yield has been linked to higher SCS. One hypothesis is that increases in yield in response to bST would be expected to result in increased SCS. The differences in this study for SCS were small between bST-treated and untreated cows. This result may indicate that the use of bST would not have an effect on SCS.

[1]Jeffrey F. Keown, professor and Extension dairy specialist, Lincoln; Bruce DeGroot, graduate student.

The Economic Impacts of Various Public-Policy Scenarios for Methane Recovery on Dairy Farms

Richard Stowell
Christopher Henry[1]

Summary

The feasibility of anaerobic digesters for dairy and swine operations in Nebraska was evaluated using EPA's Ag Star software program Farmworks 2.0 (1997) and local values for farm energy costs, mainly electricity. Four incentive programs were considered that would subsidize anaerobic digestion. Installation of a digester system is a significant investment that is currently very difficult to justify economically to Nebraska producers based on consideration of readily quantifiable income and expenses. Larger dairy operations looking to invest in this technology would benefit most from a tax credit and/or subsidized electricity sales, policies that relate directly to the production of electricity. On the other hand, small dairy farms likely would benefit more from a no-interest loan or a cost-share program – policies that relate directly to the capital cost incurred. Larger operations are more likely to place a value on odor control and would experience a lower unitized effective cost than smaller operations. The effective cost may still be unwieldy in an industry with tight profit margins, however.

Introduction

Methane recovery is often promoted as a renewable energy resource and as a means of managing manure solids and controlling odors on livestock farms. With or without generation of electricity, however, methane recovery is generally not expected to be a profitable venture for most operations in Nebraska. To better understand the costs incurred and the likely impact of public policy decisions on the feasibility of anaerobic digesters, economic analyses were performed on anaerobic digestion of manure on dairy farms and swine finishing operations. This paper focuses on results for the dairy operations. The main factors considered were herd size (100 head; 500 head; and 1,000 head) and method of financial support provided (cost-share program, no-interest loans, tax subsidies, and subsidized electrical sales).

Analysis of Anaerobic Digesters in Nebraska

EPA's Ag Star software program Farmworks 2.0 (1997) was used to evaluate the feasibility of anaerobic digesters in Nebraska. Local values for farm energy costs, propane usage, etc. were obtained to closely represent Nebraska conditions. Then, incentive programs were considered that would subsidize anaerobic digestion. First, we considered the use of a no-interest loan for capital purchases. Second, we evaluated a cost-share program that would subsidize 20% of the capital cost of installing a digester. Third, tax credits of 1/10¢ and 1¢ per kWh generated were considered. Wind power sources currently receive a 1.7¢ per kWh federal tax credit (Wiser, et. al., 2001). Finally, we considered the sale of excess generated electricity to the utility for 2¢ per kWh or 4¢ per kWh. Utilities in Nebraska generate electricity for approximately $0.02/kWh, so there is currently little incentive for them to pay that amount or more to purchase electrical power.

In our analysis, we considered what type of dairy farm would most likely use this technology. Dairy operations with confined housing for the cattle, a scrape system for manure collection and organic bedding would lend themselves best to use of a plug-flow digester. Systems having very diluted manure (flushing, treatment lagoons, runoff collection ponds, etc.), solid manure (bedded pack, separated solids, etc.), or potential sediments (e.g., sand bedding) do not lend themselves well to controlled anaerobic digestion and were not evaluated.

We also evaluated the relationship between size of operation and feasibility to determine the impact of farm scale. For this evaluation, 100 head; 500-head; and 1,000-head dairy operations were considered.

The impacts of the policy/pricing scenarios on economic return were modeled for the types and sizes of operations described. The control scenario in each case assumed the following:

- 20% down-payment made on capital investment
- Remainder financed at 8% on a 10-year loan
- Discount rate for farm capital = 10%
- Straight-line depreciation and 35% tax rate
- Operating and maintenance costs = 1.5%/year
- Electricity purchase price (retail price paid to utility) = 6¢/kWh
- Excess electricity not valued (distributed to neighbor or returned to utility free of charge)

The first five assumptions were based on general values used in similar types of evaluations. Note that we believe the 1.5% annual charge for operation and maintenance to be low, especially for smaller operations, but could not find any hard data to suggest a more appropriate value. Using limited data from systems installed in the '70s and '80s would not accurately reflect improvements implemented since then. The other assumptions were based on discussions with local livestock producers and utility representatives.

The following additional assumptions were used for dairy operations:

- Facility designed for milking herd only
- Plug-flow system
- Scrape system and organic bedding

Model Projections

Table 1 shows the capital costs for the construction of a plug-flow digester for the three size scenarios. Capital costs include: digester construction, engineering costs, engine generator, solids separator and mix tank. Excess electricity refers to electricity that cannot be used by the dairy and would be either given or sold back to the utility. The break-even price represents the price charged by the utility at which the technology may be feasible without any policy changes.

The modeled capital cost of a digester and a system for electricity generation ranged from roughly $98,000 to $296,000 or from $980 to $296 per head. These costs, illustrated in Figure 1, should be considered baseline values for a bare-bones system. Cost figures from recent farm installations indicate that total

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start-up costs are likely to exceed these values. Unfortunately, not enough installations are in place to provide more accurate values.

Some operations are fixed consumers of electricity (e.g., water heating and vacuum demands during cleaning of a milking system). As a result, smaller farms consume proportionately more energy per head, and little if any excess (saleable) electricity generation should be expected. Dairy farms commonly benefit more than other livestock enterprises from generating their own electricity because they have comparatively high demands for electricity, and farm-generated electricity decreases their demand for purchase of electricity from the utility. Where facilities and operations are not high consumers of electricity, such as naturally ventilated buildings, the technology is not as attractive.

The bottom line was that the break-even electric price (8¢/kWh) at the largest modeled herd size (1,000 cows) exceeds what most producers are paying in Nebraska (closer to 6-7¢/kWh), as shown graphically in Figure 2.

The net present value, simple payback and internal rate of return for the three direct-subsidy scenarios are shown in Table 2. Net present value (NPV) is the current value of all expected cash inflows and outflows of a project at a given discount rate over the life of the project. Simple payback is the number of years it takes to pay back the capital cost of a project calculated without discounting future revenues or costs. Internal rate of return (IRR) is the rate of return, which makes the NPV of an income stream equal to zero (Roos and Moser, 1997). Since the livestock producer is assuming risk with this investment, an economically good investment will have a positive NPV and an internal rate of return that exceeds the farm's discount rate (10% assumed).

Table 1. Modeled annual electricity production and base cost of power generation on dairy farms.

	Number of milking animals		
	100 cows	500 cows	1,000 cows
Capital cost	$98,000	$190,000	$296,000
Max. electric output	102,000 kWh	460,000 kWh	921,000 kWh
Excess electricity	0 kWh	69,000 kWh	102,000 kWh
Break-even electric cost	18¢/kWh	9¢/kWh	8¢/kWh

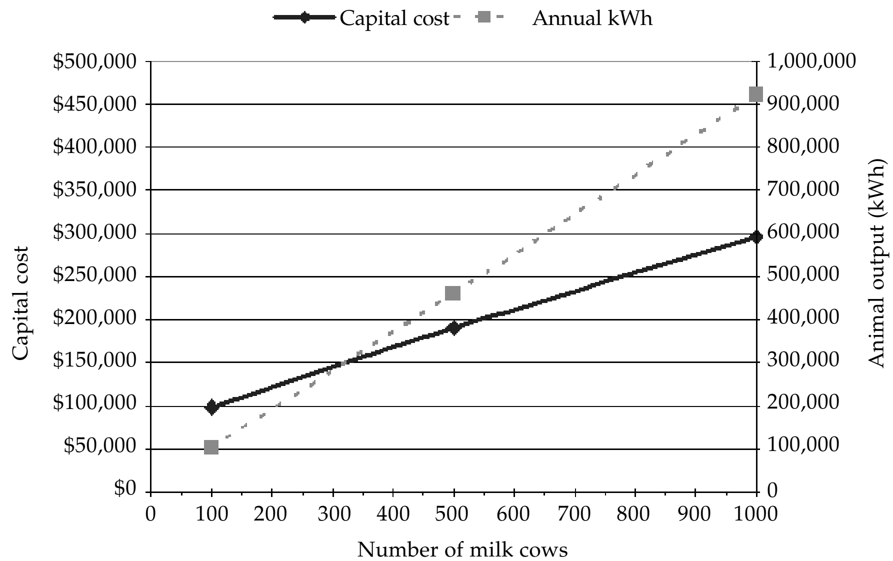

Figure 1. Modeled capital cost and electric output capacity of a digester on a dairy operation.

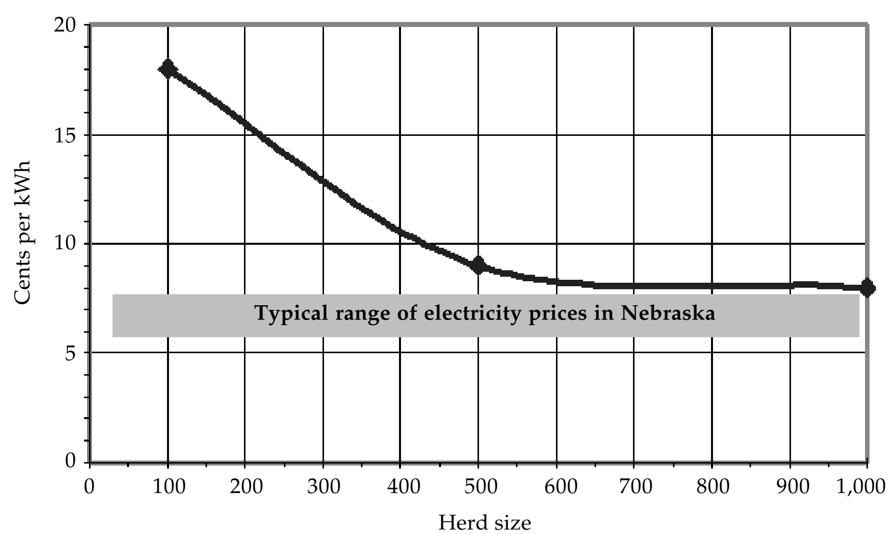

Figure 2. Modeled break-even electricity purchase price for investment in a digester.

Table 2. Modeled return on investment from electric power generation for several policy/price scenarios (as a function of size of milking herd).

	Net present value (x $1,000)			Simple payback (years)			Internal rate of return (%)		
Scenario	100	500	1,000	100	500	1,000	100	500	1,000
No policy (control)	-42	-42	-45	19.7	9.2	7.9	< 0	< 0	< 0
No-interest loan	-28	-14	-3	19.7	9.2	7.9	< 0	< 0	9
Cost-share = 20%	-30	-18	-9	15.8	7.4	6.3	< 0	< 0	3
Tax credit									
0.1¢/kWh	-42	-39	-40	19.7	9.2	7.9	< 0	< 0	< 0
1.0¢/kWh	-37	-14	10	19.7	9.2	7.9	< 0	< 0	15
Sell electricity									
2¢/kWh	NA*	-34	-21	NA	9.2	7.9	NA	< 0	< 0
4¢/kWh	NA	-25	3	NA	9.2	7.9	NA	< 0	11

*Little or no excess electricity is expected for this size operation.

Table 3. Effective cost (NPV) of methane recovery from dairy operations for odor control (no electricity generation).

	Number of milking animals					
Scenario	100 cows		500 cows		1,000 cows	
No policy (control)	$47,000	$470/hd	$88,000	$176/hd	$111,000	$111/hd
No-interest loan	$37,000	$370/hd	$72,000	$144/hd	$92,000	$92/hd
Cost-share = 20%	$39,000	$390/hd	$74,000	$148/hd	$95,000	$95/hd

Some farm operators like to see a short payback period, such as less than 5 or 10 years, while for others, an internal rate of return greater than zero or close to the loan rate is acceptable for facilities that are not expected to be primary profit centers.

Without some form of subsidy or incentive, a positive net present value or rate of return was not projected for any of the modeled herd sizes. This result indicates that methane-fueled electricity generation is not expected to be a profit center on most Nebraska livestock operations and confirms previous findings that the break-even electric price is greater than that currently charged. For 1,000 cows, the payback period was approximately 10 years, which might be viewed as acceptable by some for long-term investments which may help maintain socio-environmental acceptance.

The trends in the model output suggest that dairy operations that are significantly larger in size than modeled in this study might be able to justify a digester with electricity generation based upon the energy cost savings obtained. A more-detailed, individualized assessment is recommended for such operations.

Table 2 also shows scenarios where a dairy operation could benefit from various incentive programs or subsidies. For dairy operations with 1,000 or more cows, the opportunities to obtain a 1.0¢/kWh tax credit and to sell excess electricity for 4¢/kWh showed the greatest advantage, and were the only two scenarios showing a projected profit on the investment. On the other hand, for the 100-cow operations, greater economic benefits were derived from the no-interest loan and 20% cost-share subsidies, with the understanding that the benefit obtained would be a reduction in expected loss on the investment.

The effective cost of recovering methane only for the purpose of controlling odor is shown in Table 3. Effective cost is presented as the numerical portion of the net present value of the investment (generally negative). In these scenarios, the cost of the engine generator set was excluded and capacity to generate electricity was set to zero. We assumed that excess biogas was burned off using flares. The benefits of a no-interest loan and cost-share programs are shown compared to the current situation where there is no assistance available. Total cost of the system is shown as well as cost per head. The application of a digester solely for the purpose of odor control was projected to have an effective cost of $95 to $470 per cow depending on herd size and subsidy available.

Summary and Conclusions

Installation of a digester system is a significant investment that is currently difficult to justify economically to Nebraska dairy producers based on consideration of readily quantifiable income and

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expenses. Our projections show that methane digestion with cogeneration of electricity would not be expected to be a profitable venture for any of the farm sizes considered without some form of subsidy or other incentive, and that small operations would be hard-pressed to profit from the investment in any subsidy scenario we considered. A break-even price for electricity purchased from the utility of 8¢/kWh or higher may be required. Modest energy costs are generally advantageous to businesses in the state, but low electricity prices make energy-related investments less attractive to Nebraska producers than to producers in other regions with higher energy costs.

As the size of a livestock operation increases, the fixed capital costs of a digester system can be spread over more animal production units, making both generation of electricity and use of a digester solely for odor control more advantageous. It seems that large dairies in Nebraska and elsewhere would seem to benefit from three types of programs:

1. Tax credits (on the order of $0.01/kWh)
2. Competitive payments for sale of excess electricity ($0.04/kWh or more)
3. No-interest loans

In our analysis, these incentives appeared to make investment in methane digestion and cogeneration of electricity most feasible (i.e., had an IRR ~10%) for larger dairy operations. Synergism between the different policy programs was not considered. Perhaps two or more programs, such as a tax credit and a cost-share program, would be a more feasible scenario.

Some sort of public policy change or incentive program likely will be needed to allow this technology to penetrate the marketplace. Low retail energy prices relative to other states, a lack of consumer understanding, and the resulting difficulty in passing on increased milk production costs are major barriers to implementation of digesters on farms. Therefore, this technology may not develop in Nebraska without intervention unless retail energy costs reach break-even prices or regional restrictions on odor force the implementation of control practices.

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[1]Richard Stowell, assistant professor, Biological Systems Engineering and Animal Science, rstowell2@unl.edu; and Christopher Henry, Extension engineer, Biological Systems Engineering, chenry1@unl.edu.

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Dairy Research Herd Report

Erin Marotz[1]

This report summarizes activities at the Dairy Research Unit over the last two years and previews plans to improve our efforts in helping the dairy industry.

When I became manager in 1993, one of my goals was to obtain a 25,000 pound Rolling Herd Average. That goal has nearly been reached as of July 2003. Our current RHA stands at 24,960 lbs. milk, 75 lbs. fat and 792 lbs. protein. I would like to acknowledge everyone who has worked hard over the last 10 years to achieve this goal.

In 2003, construction of a Laboratory/Office addition to the Nutrition Research Barn was completed. The room is 20x20 and has storage space for lab equipment as well as a refrigerator and freezer for storing research samples. It also provides added flexibility when visitors come to view the Nutrition Research Barn. It has been a wonderful addition for our graduate students, staff and visitors.

In June 2003 we started construction of a hoop style barn and is divided into maternity facilities and heifer working facilities. The barn is 30x100. The maternity portion features a box/calving stall. The heifer working facilities include a scale and head gate. This barn replaces a building that was retrofitted from the old ordnance plant. This barn will increase cow comfort for maternity cows and allow renovation of an existing barn with freestalls for heifers.

In 2002 we updated the parlor by replacing the old crowd gate with a new one and added automatic identification in the parlor.

This auto ID also gives us activity levels of the cows to aid in estrus detection.

Over the past several years we have done extensive research on a wet corn gluten product called Sweetbran. This product now makes up approximately 40% of our ration on a dry matter basis. We are continuing the research with dry cows and close up cows which is the bulk of our research from a nutritional standpoint. We have also done some trials on Round-Up Ready corn and Bt corn. In August of 2002 we stopped feeding waste milk to our calves and switched to milk replacer. We implemented accelerated calf diets and so far are pleased with the results. While this has been more costly, we feel it is the best thing to do from a bio-security standpoint. We are currently conducting a reproductive trial evaluating the administration of Human Chorionie Gonadotropin 5 days post breeding to help maintain pregnancy. Data are being collected but results are not yet available.

Currently we are doing some demonstrational research on freestall beds using chipped rubber from tires as the bed and covering this with different types of covers. The chipped rubber gives an incredibly soft surface for the cows. Each stall is filled with rubber chips approximately 6-8 inches deep, which uses about 300 pounds of rubber. There is no compaction to this product. The challenge will be in the top cover with maintaining and with animal acceptance.

Our future plans are a new parlor/office building that will be worker-friendly as well as cow-friendly and within our budget. We want this building to be visitor-friendly as well. Our goal is to be in this new building in three years. We would also want to develop a web site in the near future to feature our unit and to allow people to take a virtual tour.

The Dairy Research Unit is located 4.5 miles south of Mead on the University's Agricultural Research and Development Center. Our phone number is (402) 624-8068 and my e-mail address is emarotz1@unl.edu. Feel free to contact us for any reason or stop by if you are in the area. Due to bio-security concerns, please contact us ahead of time for a tour.

[1]Erin Marotz, manager, Dairy Research Unit, Mead.

Modeling Genetic and Environmental Effects of Test Day Records by Autoregressive Covariance Structures

Rami Sawalha
Jeffrey F. Keown

Introduction

Test-day (TD) models have been extensively investigated for dairy cattle production evaluation. They have been suggested to replace the currently used adjusted cumulative 305-day records. TD models allow direct evaluation and hence adjustment for genetic and environmental effects for each individual TD record. Current accounting for genetic and environmental correlation between test-days ranges from assuming unitary correlation between TD records to the use of character processing and random regression. Complex models are generally computationally demanding and may not be possible to include multiple lactations and consequently not proper to explain the between lactation variation. Adjacent and close in time records are expected to be more highly correlated than far apart in time records. Moreover, with the hypothesis of unitary perfect) genetic correlations, all test-day records are assumed to be affected by the same genes regardless of stage of lactation or parity. The autoregressive repeatability model relaxes the unitary assumption of the repeatability animal model. It allows for estimating and consequently use of unnecessarily equal correlations between TD both within and across lactations. With this model, fewer parameters are needed to be estimated compared with other models that can account for TD correlations. In this research, the autoregressive repeatability animal model is used to account for both genetic and environmental correlations between TD records in several lactations.

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Data and Model

Test-day records were obtained from the Dairy Records Management Systems (DRMS) in Raleigh, N.C. More than 46, 000 completed records were pulled out of more than 1 million records from 1994 to 2002. These records were chosen to represent typical dairy Holstein cows under a wide spectrum of environmental and genetic backgrounds. Effects considered in the analysis loche (?) varied in contemporary group effects of herd-test-date, milking frequency, bST treatment and season of freshening. Data included the first three lactations with some cows missing second and/or third records. The genetic and the environmental covariance structures included 30 X 30 autoregressive matrix for each individual animal. Only one correlation parameter needs to be estimated for environmental effects and one for genetic effects. Correlation between two records on a cow will depend on how far apart in days the records are from each other. The timing will determine the strength of one correlation. This model will be challenged to estimate variance components and predict breeding values. The model will be compared with the currently used model that uses adjusted cumulative 305-day records. Models will also be compared with regard to ability to predict future records. For that comparison, some TD records will be intentionally made missing and the ability of the model to predict them will be measured using prediction of mean square error of prediction.

[1]Rami Sawalha, graduate student; and Jeffrey F. Keown, professor and Extension dairy specialist.

Effect of Human Chorionic Gonadotropin on Reproductive Performance of Lactating Dairy Cows

Larry Larson[1]

Summary

A study has been initiated to evaluate the effect of human chorionic gonadotropin (hCG) administration on day 5 after a timed AI on reproductive performance. Lactating Holstein cows are being assigned to either a control group (no treatment) or a hCG treatment group. The breeding program is being initiated after a voluntary waiting period of 66 days. A timed AI program is being used to ensure that all cows receive their first insemination at the desired time postpartum. Reproductive data are being collected but results are not yet available.

Introduction

Pregnancy rates to first service have declined to 40% and are often lower in early lactation cows. Early embryo death often occurs around day 5-7 after estrus and breeding, just after the embryo enters the uterus. These losses, in addition to fertilization failures, are greater in repeat-breeding cows. Losses of embryos at this stage of pregnancy generally are not detected because the cow returns to estrus at a regular interval. The next critical stage is around day 15-16 after estrus when the embryo must be developed sufficiently to override the spontaneous uterine secretion of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$), which normally causes the corpus luteum (CL) to regress. Embryonic losses between day 27 and 98 after breeding have been estimated to vary from 7 to 56% across many herds. In one herd, embryonic losses between 28 and 56 days were 43% compared to only 20% in contemporary cows treated with progesterone prior to AI. Administration of 3000 IU hCG on day 5 of the estrous cycle of Holstein heifers induced formation of an accessory CL and subsequently higher progesterone concentrations between days 9 and 17. The hCG treatment on day 5 induced more 3-wave follicular cycles vs. 2-wave cycles, which may increase embryonic survival and/or enhance conception rates during the next cycle. Another study found that treatment with hCG, 3300 IU i.m., on day 5 after AI induced accessory CL, enhanced plasma progesterone concentrations, and improved conception rate of high-producing dairy cows in a commercial herd located in south central California.

Cows must be pregnant by 85 to 115 days in milk (DIM) to obtain a 12 to 13 month calving interval that in the past has been accepted as optimal. However, producers commonly initiate the breeding program between 45 and 60 DIM because of low estrus detection rates (<50%) and low conception rates (<50%). This results in some cows becoming pregnant before the desired interval and others later than the desired interval. Pregnancy rates increase as the days postpartum to breeding interval increases. Previous studies have shown that using a timed AI protocol can insure that all cows receive their first insemination at the desired time.

It is hypothesized that hCG administration to cows on day 5 after a timed AI protocol will increase the percentage of cows that become pregnant at the desired interval postpartum by increasing conception rate at first service and the maintenance of pregnancy.

Procedures

Lactating Holstein cows will be blocked by calving date and parity and assigned randomly to one of the following two treatments: 1. control, no hCG treatment; or 2. 3300 IU hCG. The hCG will be administered i.m. on day 5 after a timed AI to stimulate the formation of accessory corpora lutea.

The breeding program will be scheduled so that the first AI will occur after a voluntary waiting period of 66 days. A modified timed AI (TAI) program (Heatsynch) will be used to ensure that all cows receive their first insemination at the desired time. The TAI protocol involves a treatment period of 38 days, so the TAI protocol will be initiated at 28 DIM allowing first AI to occur at 66 DIM. Cows will be presynchronized with two injections of $PGF_{2\alpha}$ (25 mg, i.m.), given 14 days apart with the second injection given 14 days before initiating the Heatsynch protocol. The Heatsynch protocol, consists of gonadotropin releasing hormone (GnRH, 100 ug, i.m.), followed 7 days later with an injection of $PGF_{2\alpha}$, followed with an injection of estradiol cypionate (ECP,1 mg, i.m.) 24 hours after the $PGF_{2\alpha}$, and AI 48 hours after ECP. Cows detected in estrus by 24 hours after ECP will be inseminated at 24 hours and all remaining cows inseminated at 48 hours after ECP.

Cows that return to natural estrus will be assigned to receive the same hCG treatment at the repeat service as they received at the first TAI. Cows not observed returning to estrus but diagnosed as not pregnant will be placed on the Heatsynch program a second time and given the same hCG treatment as before.

Reproductive measurements being collected include:

1. Conception at the fixed-time AI
2. Pregnancy rate at 180 DIM
3. Days from start of breeding program to conception

Continuous variables will be analyzed by ANOVA using the general linear models procedure of SAS (1990). Chi-square (SAS, 1990) will be used to analyze frequency data. Findings from this experiment will determine the possible benefit of HCG to improve conception rates.

Results

The trial is in progress and results are not yet available.

[1]Larry Larson, associate professor, Animal Science.

A Corn Hybrid With High Cell Wall Content and Digestibility and Lactational Performance of Holstein Cows

Sarah Ivan
Rick Grant[1]

Summary

We hypothesized that substituting a corn hybrid with high cell-wall content and NDF high digestibility (HCW) for a hybrid with lower cell-wall content and lower NDF digestibility (LCW) would improve feed intake and milk production in lactating Holstein cows. In trial 1, 40 cows ranging in milk production from 53.1 to 97.0 lb/day, after a 2-week preliminary period, were used in a crossover design with 2-week periods. Diets consisted of 45% corn silage (HCW or LCW), 10% alfalfa hay and 45% concentrates. There was a 3.6 percentage-unit range in NDF content and a 4.1 percentage-unit range in 30-hour in vitro NDF digestion between the two corn hybrids. The DMI (56.0 vs. 53.4 lb/day) and 4% FCM yield (75.6 vs. 69.9 lb/day) were higher for cows fed the HCW diet compared with the LCW diet. Milk composition was unaffected by diet. When HCW was substituted for LCW on a DM basis, there was no relationship between pretrial milk yield during the preliminary period and response to HCW silage. In trial 2, 40 cows ranging in milk production from 45.4 to 108.0 lb/day, after a 2-week preliminary period, were used in a crossover design with 2-week periods. Diets consisted of the same LCW diet as trial 1 and a diet containing HCW at a concentration (40% of DM) that resulted in equal NDF content (30.8%) between the two diets (HCWN). The DMI (59.1 lb/day) was unaffected by diet, although there was a trend for greater DMI (% of BW)

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for cows fed the HCWN diet compared with LCW silage (4.24 vs. 4.12). Milk fat (3.91 vs. 3.79%) and 4% FCM yield (76.9 vs. 73.6 lb/day) were greater for cows fed HCWN versus LCW diet. When HCW was substituted for LCW silage on a NDF the cows with greater milk production during the preliminary period had a greater milk response to HCW than lower producing cows. Results of these trials supported our hypothesis that HCW corn silage results in greater DMI and milk yield than LCW silage, whether substitution occurs on a DM or NDF basis.

Table 1. Nutrient composition of silages used in Trials 1 and 2 (DM basis).

Item	Silages[a]		
	LCW	HCW	Preliminary
DM, % as fed	36.2	35.7	30.2
CP, %	9.6	8.8	9.5
NDF, %	49.2	52.8	48.0
ADF, %	31.3	31.8	28.3
Lignin, %	4.0	3.8	3.3
Starch, %	25.7	22.5	24.7
IVSD-8 h[b], %	99.1	98.8	ND
IVNDFD-30 h[c], %	50.7	54.8	ND
IVNDFD-48 h[c], %	58.2	66.7	ND
Fermentation profile			
pH	3.97	3.99	3.87
Total acids, %	8.8	7.6	12.2
Lactic acid, %	5.5	6.0	8.8
Acetic acid, %	2.9	1.1	3.1
Lactic/acetic	2.1	6.2	2.8
Propionic acid, %	0.3	0.1	0.2
Butyric acid, %	0.1	0.4	0.1
Isobutyric acid, %	0.1	0.0	0.0
Ammonia N, % of total N	9.6	9.4	8.8
Particle size distribution of DM[d], % of total DM			
Top (>0.75 in)	4.4	3.7	6.7
Middle (0.31 to 0.75 in)	50.3	47.5	75.6

[a]LCW = low cell wall content and digestibility, HCW = high cell wall content and digestibility silage, HCW = high cell wall content and digestibility silage, and Preliminary = silage fed during 2-week preliminary period.
[b]In vitro rumen NDF digestibility measured after 8 hours of incubation.
[c]In vitro rumen NDF digestibility measured after 30 or 48 hours of incubation.
[d]Measured using the Penn State Particle Size Separator (Lammers et al., 1996).
ND = not determined.

Introduction

The high NDF content of forages helps to alleviate intake and health problems associated with highly digestible diets by increasing rumination time, which increases saliva production. Saliva helps to buffer the rumen from extreme changes in pH, and in dairy cattle we tend to be most concerned about drops in pH, which implies an acidotic condition. Feeding a high-NDF corn silage also would allow for lower concentrations of forage in the ration to meet the same minimum NDF requirements, which would decrease the amount of forage that would have to be grown or purchased. However, the same NDF that helps to prevent acidosis can also be detrimental to intake and production if fed at high levels. As concentration of NDF in the forage increases, DM digestibility decreases, which then decreases dry matter intake of the cow. Forages with lower digestibility result in bulk fill in the rumen, which inhibits further intake. Therefore, a high-NDF corn silage would be beneficial only if the increased NDF did not limit intake through decreased DM digestibility and bulk fill in the rumen.

Higher producing cows have greater DMI, and therefore, their intake is more likely to be limited by rumen fill compared with cows that are producing less milk. When feed intake is limited by fill, one approach to increase DMI is to increase NDF digestibility, which increases the rate of NDF clearance from the rumen thereby creating additional space in the rumen. This allows for increased intake, which should result in increased milk production. Therefore, the ability to relate the response to the increased digestibility silage back to initial milk production becomes important to help develop optional feeding strategies.

Recently a corn hybrid was developed that has higher NDF content, which provides the benefits of a high NDF forage, but with more digestible NDF, which will decrease the filling effects of high NDF forages and potentially allow for increased intake. Therefore, the objectives of this research were: 1) to compare the effect of a high NDF, high NDF digestibility corn silage with a lower NDF, lower NDF digestibility corn silage on feed intake and milk production and composition, and 2) to relate the response in milk yield back to initial milk production.

Procedures

Trial 1: Forage Substitution on a DM Basis

Forty Holstein cows ranging in milk production from 53.1 to 97.0 lb/day were assigned to a crossover design after a 2-week preliminary period. Cows were housed in a tie-stall barn and were allowed ad libitum access to diets. The chemical composition and particle size distribution of the corn silages are shown in Table 1. Both hybrids were cut at 3/4 milk line stage of maturity at a 0.375 inch theoretical length of cut without kernel processing or inoculation and stored in Ag bags until initiation of Trial 1. The HCW corn silage was 3.6

Table 2. Ingredient and chemical composition of diets used in Trials 1 and 2.

	Silages[a]			
Item	LCW	HCW	HCWN	Preliminary
Ingredient, % of DM				
Alfalfa hay	10.0	10.0	10.0	10.0
Bunker silage	—	—	—	45.1
LCW corn silage	45.1	—	—	—
HCW corn silage	—	45.1	40.1	—
Corn, ground	23.1	23.1	28.1	23.1
Tallow	1.0	1.0	1.0	1.0
Soypass[b]	1.8	1.8	1.8	1.8
Soybean meal	14.4	14.4	14.4	14.4
Blood meal	0.9	0.9	0.9	0.9
Mineral and vitamin mix[c]	3.7	3.7	3.7	3.7
Composition, % of DM[d]				
DM, %	52.6	50.3	58	49.7
CP	18.2	17.9	18.5	18.5
RUP[e]	6.3	6.3	6.4	6.3
ADF	19.6	19.7	18.5	18.4
NDF	30.8	33.2	30.8	31.6
Lignin	3.0	2.7	3.0	2.5
Starch	28.0	29.5	30.3	27.2
Particle size distribution of DM[f], % of total DM				
Top (>0.75 in)	9.8	7.4	8.9	8.3
Middle (0.31 to 0.75 in)	19.3	19.5	16.7	37.0

[a]LCW = diet containing low cell wall content and digestibility corn silage, HCW = diet containing high cell wall content and digestibility corn silage substituted on DM basis, HCWN = diet containing high cell wall content and digestibility silage substituted on a NDF basis, and Preliminary = diet fed during 2-week preliminary period.
[b]Nonenzymatically browned soybean meal (Lignotech USA, Rothschild, WI).
[c]Supplement contained 21.1% Ca, 2.7% P, 3.1% Mg, 7.7% Na, 1,223 ppm of Zn, 854 ppm of Mn, 152 ppm of Cu, and 145,200, 29,040, and 921,800 IU per kilogram of Vitamin A, D, and E, respectively.
[d]Calculated from chemical composition of individual ingredients.
[e]Calculated using NRC (2001) values for individual ingredients.
[f]Measured using Penn State Particle Size Separator (Lammers et al., 1996).

percentage-units higher in NDF and 4.1 percentage-units higher in 30-hour in vitro NDF digestibility compared with the LCW silage. Due to the differing NDF concentrations of the corn silages, the diets were balanced to contain either 29.2 or 31.6% NDF for the LCW and the HCW diets, respectively. The diets (Table 2) consisted of either 45.1% of a high cell-wall and high digestibility corn silage (HCW) or 45.1% of a lower cell wall and lower digestibility corn silage (LCW). The remainder of both diets consisted of alfalfa hay and concentrate. The concentrate portion of the diet consisted of ground corn, tallow, Soypass®, soybean meal blood meal, and mineral and vitamin mix.

Trial 2: Forage Substitution on a NDF Basis

Forty Holstein dairy cows ranging in milk production from 45.4 to 108.0 lb/day were assigned to a crossover design after a 2-week preliminary period. Cows were housed in a tie-stall barn and were allowed ad libitum access to diets. The diets (Table 2) consisted of either 40.1% of the HCW silage or 45.1% of the LCW silage. The LCW diet contained the same ingredients and concentrations as the LCW diet in Trial 1. In Trial 2, the diet containing the HCW silage (HCWN) was formulated to contain a NDF concentration equal to that in the LCW diet (29.5% for HCWN diet and 29.3% for the LCW diet). The HCWN diet contained alfalfa hay and concentrate. Ground corn replaced the corn silage in the HCWN diet. The other ingredients in the concentrate mix remained the same as the HCW diet from Trial 1.

Trials 1 and 2: Sampling and Measurements

For both trials, the experimental periods were 14 days; the last 7 days were used for data collection of samples. Diets were fed once daily with the intent to have 10% orts. Amounts offered and orts were recorded daily to determine DMI. Body weights were taken at the beginning and end of each experimental period. Daily milk production was recorded and milk composition samples were collected at four consecutive milkings and analyzed for fat, protein, and lactose.

Feed samples were collected and analyzed in a similar manner for both Trials 1 and 2. Corn silages, alfalfa hay, concentrate and TMR samples were collected during the last week of each period for chemical analyses. Samples were oven-dried (60ºC) and ground through a Wiley Mill (1-mm screen) and analyzed for CP, NDF, ADF, acid-detergent lignin, and starch. Corn silages were analyzed for 30-hour and 48-hour in vitro NDF digestibility (IVDNFD) and for 8-hours in vitro starch digestibility (IVSD). The Penn State Particle separator was used to determine particle size distribution of fresh corn silage and TMR samples. A fresh silage sample was used to determine silage pH and a portion was frozen for later determination of the fermentation profile.

Results

Corn Silage and Dietary Nutrient Composition

The average nutrient composition of the two experimental

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silages and the preliminary corn silage fed during the two trials is shown in Table 1. The NDF concentration was 3.6 percentage-units higher for the HCW silage compared with the LCW silage but the acid detergent fiber and lignin concentration were not different. The starch concentration was lower in the HCW silage (22.5%) compared with the LCW silage (25.7%). The in vitro starch digestibilities, after 8 hours of incubation, averaged 99% and were not different for the two experimental silages. The 30-hour in vitro NDF digestibility was higher for the HCW silage compared with the LCW silage (54.8% versus 50.7% for the HCW and LCW silages, respectively). The 48-hour in vitro NDF digestibility was also higher for the HCW silage (66.7%) than for the LCW silage (58.2%).

The fermentation profiles of the two experimental silages were similar (Table 1). The lactic acid concentration was slightly lower and the acetic acid concentration was higher in the HCW silage, which led to a difference in the lactic acid to acetic acid ratio. Overall, the pH and the VFA concentrations indicate good silage fermentation. The particle size distributions of the two experimental silages were similar. The silage fed during the preliminary period contained similar nutrient composition to the LCW silage.

The diets fed during the experimental periods of Trials 1 and 2, plus preliminary period diet, contained similar concentrations of DM, CP, RUP, ADF and starch (Table 2). The distributions of the particle size of the three experimental diets were similar when measured as-fed. As planned, the HCW diet contained 33.2% NDF compared with the LCW diet which contained 30.8% NDF, resulting in a difference of 2.4 percentage-units of NDF between the two diets (Table 2). The HCW corn silage was known to contain a higher NDF concentration, so replacing the LCW silage with the HCW silage, on a DM basis, should have resulted in a predictably higher NDF content for that diet.

In summary, the primary differences between the LCW and the HCW corn silages were the content of NDF (3.6 percentage-units) and the digestibility of the NDF (4.1 percentage-units for 30-hour in vitro digestion; 8.5 percentage-units difference for 48-hour in vitro NDF digestion).

Table 3. Milk yield and composition as influenced by experimental diets (Trial 1).

	Diets[a]			
Item	LCW	HCW	SEM	*P*
Milk, lb/d	73.9	78.7	1.3	<0.01
4% FCM, lb/d	69.9	75.6	1.3	<0.01
Milk fat				
%	3.68	3.75	0.08	0.38
lb/d	2.69	2.93	0.07	<0.01
Milk true protein				
%	2.91	2.93	0.03	0.54
lb/d	2.14	2.29	0.04	<0.01
Milk lactose				
%	4.89	4.85	0.04	0.24
lb/d	3.61	3.81	0.09	0.03
Milk SNF				
%	8.72	8.68	0.07	0.61
lb/d	6.43	6.81	0.15	0.01
DMI, lb/d	53.4	56.0	1.1	0.05
DMI, % of BW	3.95	4.21	0.10	0.01
4% FCM/DMI, lb/lb	1.32	1.36	0.04	0.24

[a]LCW = diet containing the low cell wall content and digestibility corn silage, HCW = diet containing the high cell wall content and digestibility substituted on a DM basis.

Table 4. Milk yield and composition as influenced by experimental diets (Trial 2).

	Diets[a]			
Item	LCW	HCW	SEM	*P*
Milk, lb/d	76.3	78.3	1.1	0.14
4% FCM, lb/d	73.6	76.9	1.3	0.03
Milk fat				
%	3.79	3.91	0.06	0.07
lb/d	2.87	3.04	0.07	0.03
Milk true protein				
%	3.07	3.12	0.03	0.13
lb/d	2.31	2.43	0.04	0.07
Milk lactose				
%	4.79	4.83	0.04	0.36
lb/d	3.66	3.79	0.07	0.10
Milk SNF				
%	8.79	8.88	0.07	0.23
lb/d	6.68	6.94	0.13	0.09
DMI, lb/d	58.4	59.7	1.1	0.32
DMI, % of BW	4.12	4.24	0.08	0.13
4% FCM/DMI, lb/lb	1.28	1.31	0.03	0.39

[a]LCW = diet containing the low cell wall content and digestibility corn silage, HCWN =

Trial 1: Forage Substitution on a DM Basis

Milk Yield, Milk Composition, and DMI. The milk yield (78.7 and 73.9 lb/day for HCW and LCW, respectively) and 4% FCM (75.6 and 69.9 lb/day for HCW and LCW, respectively) were significantly higher for cows fed the HCW diet compared with the LCW diet (Table 3). For a one–percentage-unit increase in NDF digestibility, the 4% FCM yield increased by either 1.39 lb/day (30-hour in vitro NDF digestion) or 0.68 lb/day (48-hour in vitro NDF digestion). No difference was observed in the gross efficiency of converting DMI to 4% FCM. Due to the increase in milk yield, production of milk fat, milk true protein, lactose and SNF were all significantly greater for the HCW diet. Increases in milk yield and 4% FCM were most likely due to the significant increase in DMI observed for cows fed the HCW diet (56.0 lb/day) compared with the LCW diet (53.4 lb/day; Table 3). This difference was also significant when converted to a percentage of BW basis indicating that the response was not simply a function of larger cows eating more because they have higher ruminal capacity. A one-percentage-unit increase in NDF digestion was associated with a 0.64 lb/day increase in DMI (30-hour in vitro NDF digestion) or 0.31 lb/day (48-hour in vitro NDF digestion).

Relationship of Milk Response to Pretrial Milk Yield. The second objective of this study was to evaluate how pretrial milk production affected the response to the high NDF, high NDF digestibility corn silage. In this trial, where HCW silage was substituted on a DM basis, there was no effect of initial milk yield on subsequent response to diet in terms of milk yield or energy-corrected milk yield. Overall, however, 70% of the cows on the HCW diet had a positive response compared to the LCW diet.

Trial 2: Forage Substitution on a NDF Basis

Milk Yield, Milk Composition and DMI. There was a trend for increased milk yield for the HCWN diet compared with the LCW diet and 4% FCM was significantly greater for cows fed the HCWN diet (Table 4). In this trial, substituting the HCW silage, on an NDF basis, the LCW silage resulted in lower inclusion of the HCW silage. Therefore, the benefit of the increased digestibility of this silage may not be as pronounced due to its lower concentration in the diet. However, for 30-hour IVNDFD a 0.66 lb increase was observed in 4% FCM production for a one-percentage-unit increase in NDF digestibility. Using the 48-hour IVNDFD value resulted in a smaller increase in 4% FCM per one-percentage-unit increase in digestibility (0.37 lb). Interestingly, milk fat concentration for the HCWN diet increased significantly compared with the LCW diet. The overall forage concentration of the diet while maintaining the NDF concentration of the diet, which not only prevented a depression in milk fat concentration, but actually increased milk fat concentration in the HCWN diet. The milk true protein concentration of the HCWN diet tended to increase. The increased energy available to the rumen may have provided a better balance between energy and protein to the ruminal microflora thereby increasing microbial protein synthesis and consequently metabolizable protein supply to the cow. The concentration of lactose and SNF were not affected by treatment, but due to the increase in milk yield, the yield of all milk components increased in cows fed the HCWN diet compared with the LCW diet. As observed in Trial 1, treatment did not affect efficiency of converting DMI to 4% FCM. The DMI response followed the milk yield response (Table 4). There was a trend for an increase in DMI for cows fed the HCWN diet compared with the LCW diet as a percentage of BW.

Relationship of Milk Response to Pretrial Milk Yield. When high NDF content and digestibility with corn silage was substituted on a NDF basis there was a significantly greater effect of pretrial milk production on the response to the HCWN diet compared with the LCW diet. In terms of milk yield, there was a linear relationship indicating that cows with higher production pretrial were able to respond to a greater extent to the HCWN diet than cows that were at lower levels of production. For energy-corrected milk the response was quadratic so that cows that were producing approximately 80 lbs/day pretrial produced 6 to 8 lbs/day more on the HCWN diet then they did on the LCW diet. In general a one-percentage-unit increase in pretrial milk yield resulted in a 0.33 lb increase in response to the diet containing the higher NDF, higher NDF digestibility silage. We believe this response can be explained by the fact that higher producing cows were also eating more so their intake was more likely to be limited by bulk fill in the rumen. The conclusion was that feeding a higher digestibility corn silage will allow feed to turn over faster in the rumen creating additional space which would allow increased intake and greater milk production.

Substitution of a corn silage with higher NDF content and digestibility for a silage with lower NDF content and digestibility, on either a DM or an NDF basis, resulted in increased feed intake and milk production for those cows. Substitution of this high NDF content and digestibility silage on a NDF basis for a conventional silage seemed to have an added benefit for higher producing cows by possibly alleviating rumen fill which would allow for increased intake and milk yield.

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[1]Sarah Ivan, graduate student, Rick Grant, professor and Extension dairy specialist, Animal Sciences.

Comparison of Brown Midrib-6 and 18 Forage Sorghum with Conventional Sorghum and Corn Silage in Diets for Lactating Dairy Cows

Rick Grant
Amanda Oliver
Jerry O'Rear[1]

Summary

Total mixed rations containing conventional forage sorghum, brown midrib (bmr)-6 forage sorghum, bmr-18 forage sorghum, or corn silage were fed to Holstein dairy cows to determine the effect on lactational performance, ruminal fermentation and total tract nutrient digestion. Sixteen multiparous cows (four ruminally fistulated; 124 days in milk) were assigned to one of four diets in a replicated Latin square design with 4 week periods. Diets comprised 40% test silage, 10% alfalfa silage, and 50% concentrate mix (dry basis). Acid-detergent lignin concentration was reduced for the bmr-6 and bmr-18 sorghum silages when compared with the conventional sorghum. Dry matter intake was greater for cows fed the bmr-6 sorghum compared with the conventional sorghum, bmr-18 sorghum and corn silages were intermediate. Production of 4% fat-corrected milk was greatest for cows fed bmr-6 and corn silage, least for cows fed the conventional sorghum, and intermediate for bmr-18 sorghum. Total tract neutral detergent fiber (NDF) digestibility was greatest for bmr-6 sorghum and corn silage diets, and least for conventional and bmr-18 sorghum diets. In situ extent of NDF digestion was greatest for the bmr-6 sorghum and corn silage, least for conventional sorghum, and intermediate for the bmr-18 sorghum silage. Results of this study indicate that bmr-6 sorghum hybrid outperformed the conventional sorghum hybrid with bmr-18 sorghum being intermediate in most cases. Additionally, the bmr-6 hybrid resulted in lactational performance equivalent to the corn hybrid used in this study. There are important compositional differences among bmr forage sorghum hybrids that need to be characterized to accurately predict the animal response to feeding the sorghum silage.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench.] has become an increasingly important forage crop for dairy producers in the Midwestern and Plains regions of the United States. In addition to the drier Plains states, recurring climatic conditions in other regions of the U.S., such as drought, high summer temperatures, or delayed planting introduce considerable risk into corn (*Zea mays* L.) production for silage. Thus, many dairy producers consider silage-type sorghums as a viable alternative crop. Forage sorghums can be planted later than corn, use water much more efficiently, have high biomass yields, and when exposed to drought, still produce acceptable silage yields.

However, the DM digestibility of many corn hybrids is typically greater than for conventional forage sorghum hybrids. Lignin, the primary indigestible component of plant cell walls, limits digestion of cell wall carbohydrates in the rumen. Ordinarily the whole corn plant contains less lignin than commonly fed sorghum hybrids, as well as a greater content of grain. Because higher lignin concentration reduces the potential extent of ruminal fiber digestion, it often results in increased ruminoreticular fill, reduced DMI, and less milk production for cows fed conventional forage sorghum hybrids.

Chemical and genetic approaches have been employed to improve forage fiber digestibility by reducing the amount of lignin or the extent of lignin cross linking with cell wall carbohydrates. Previous research has indicated brown midrib **(bmr)** forage genotypes usually contain less lignin and may have altered lignin chemical composition. To-date, genetic control of the lignification process through manipulation of the bmr trait has offered the most direct and productive approach to reducing lignin content and increasing digestibility of forage sorghums. In situ and in vitro digestion studies have shown that bmr forages have greater extent of NDF digestion than their conventional counterparts. Previous research at the University of Nebraska observed greater milk production for Holstein dairy cows fed bmr forage sorghum versus conventional forage sorghum, with milk production similar to cows fed corn silage.

Even though it is often not specified in research reports, there

Table 1. **Chemical composition of the experimental silages (% of DM).**

Item	Forage sorghum			
	Normal	bmr-6[1]	bmr-18	Corn silage
DM, %	30.6	32.9	34.1	34.4
CP 7.3	7.5	7.8	8.4	
ADF37.7	33.6	28.5	28.5	
NDF58.1	50.2	48.2	46.1	
Starch	10.9	16.8	14.5	19.9
ADL[2]	2.89	2.30	2.52	2.64
$KMnO_4$ lignin[3]	8.8	6.90	6.22	5.53
Ash 4.1	4.5	3.3	2.7	
PH 4.00	4.08	4.03	3.90	
Particle distribution				
>19 mm	8.6	6.5	9.8	19.7
19 mm to 8 mm	49.9	50.4	60.5	63.5
< 8 mm	41.4	43.0	29.7	16.8

[1]Brown midrib.
[2]Acid detergent lignin.
[3]Lignin measured by permanganate procedure.

Table 2. Ingredient and chemical composition of experimental diets.

Item	Normal	bmr-6[1]	bmr-18	Corn silage
Ingredients, % of DM				
Alfalfa hay[2]	10.0	10.0	10.0	10.0
Normal sorghum silage	40.0	—	—	—
BMR-6 sorghum silage	—	40.0	—	—
BMR-18 sorghum silage	—	—	40.0	—
Corn silage	—	—	---	40.0
Wet corn gluten feed[3]	22.7	22.7	22.7	22.7
Whole linted cottonseed[4]	3.7	3.7	3.7	3.7
Grain mixture[5]	23.6	23.6	23.6	23.6
Composition, % of DM				
DM, %	59.3	60.2	60.7	60.8
CP	17.6	17.7	17.8	18.0
RUP[6]	6.8	6.8	6.8	6.7
ADF	24.4	22.8	20.8	20.7
NDF	43.2	40.1	39.3	38.3
Starch	17.4	19.7	18.8	21.0
ADL[7]	2.78	2.54	2.63	2.62
$KmnO_4$ lignin[8]	6.14	5.38	5.11	5.12
Ash	4.5	4.6	4.2	3.9
Particle distribution				
> 19 mm	35.2	14.7	33.6	23.1
19 mm to 8 mm	13.1	13.9	7.7	22.6
< 8 mm	51.7	71.4	58.7	54.3

[1]Brown midrib.
[2]Alfalfa hay contained (DM basis) 21.6% CP, 35.2% ADF, 29.6% NDF, 2.23% ADL, 11.0% permanganate lignin, and 5.9% ash.
[3]Wet corn gluten feed contained (DM basis) 23.6% CP, 12.1% ADF, 43.0% NDF, 2.0% ADL, 2.5% permanganate lignin, and 2.5% ash.
[4]Whole linted cottonseed contained (DM basis) 23.9% CP, 45.8% ADF, 50.1% NDF, 12.9% ADL, and 3.4% ash.
[5]Grain mixture was comprised of 52.1 % ground dry corn, 34.7% soybean meal (46.5% CP), 3.3% blood meal, 3.3% limestone, 2.2% tallow, 1.6% sodium bicarbonate, 1.5% dicalcium phosphate, 0.5% salt, 0.35% magnesium oxide, and 0.6% of a micromineral and vitamin premix.
[6]Ruminally undegraded protein was calculated using values reported by NRC (2001).
[7]Acid detergent lignin.
[8]Lignin measured using the permanganate procedure.

are three bmr loci (bmr-6, bmr-12, and bmr-18; bmr-12 and bmr-18 may be allelic) which have been identified in sorghum. The recent research with forage sorghum fed to lactating dairy cows used a bmr-6 forage sorghum hybrid. However, chemical differences resulting from different mutations in the lignin biosynthesis pathway may exist among bmr-6, bmr-12, or bmr-18 hybrids. To-date, no research has compared different bmr hybrids for their effect on dairy performance relative to conventional sorghum or corn silage.

Therefore, the objective of this experiment was to determine the effect of a conventional forage sorghum, bmr-6 forage sorghum, bmr-18 forage sorghum, or a dual-purpose corn hybrid on lactational performance, ruminal fermentation, and total tract nutrient digestibility in Holstein dairy cows.

Procedures

All forages used in this experiment were harvested in the fall of 2001 at the University of Nebraska Agricultural Research and Development Center located near Mead, Neb. Conventional, bmr-6, and bmr-18 (SG-SileAll, SG-BMR100, SG-XP-18; Garrison and Townsend Inc., Hereford, Texas) forage sorghums were grown in adjacent fields without irrigation and harvested at the late-dough stage of maturity. The sorghum hybrids were harvested using a field chopper with knives adjusted to a 1-cm theoretical length of cut. The yield of the conventional forage sorghum was 18.7 tons/acre (DM basis), bmr-6 yielded 12.4 tons/acre (DM basis), and bmr-18 yielded 17.2 tons/acre (DM basis). Nonirrigated corn silage (Pioneer 34R07; Pioneer Hi-Bred Intl., Des Moines, Iowa) was harvested at 2/3 milk line stage of maturity with a field chopper with knives

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adjusted to a 1-cm theoretical length of cut. The yield of the corn silage was around 16 tons/acre (DM basis). All four forages were ensiled without use of inoculants in separate plastic silage bags prior to the start of the experiment. The chemical composition of the experimental silages is summarized in Table 1.

Sixteen multiparous Holstein cows (four ruminally fistulated) were used in a replicated Latin square design with 4-wk periods; the first 21 days served as an adaptation period and the last 7 days as a collection period. Cows averaged 124 $\pm$ 28 DIM when they were assigned to diets. Diets contained approximately 40% test silage, 10% alfalfa silage, 3.7% whole cottonseed, 22.7% wet corn gluten feed, and 23.6% of a concentrate mix comprised of ground corn, soybean meal, blood meal, minerals, and vitamins (Table 2). Diets were formulated to contain similar CP and RUP, and to differ in NDF and lignin content due to source of silage. Cows were housed in a tie-stall barn and fed using individual feed boxes. Diets were fed as TMR and offered once daily in amounts to ensure 10% refusal; offered and refused feed were recorded daily. Cows were removed from the barn twice daily for milking, exercise, and estrus detection for a total of approximately 4 hours.

A weekly sample of each silage, TMR and other dietary ingredients was collected, composited by period and analyzed for chemical composition. Silage pH was measured on fresh silage samples. Composite samples were oven-dried (60ºC), ground though a Wiley mill and analyzed for CP, ADF, ADL, permanganate lignin, phosphorus and starch. Particle size distribution (as-fed basis) was determined using the Penn State particle separator.

Daily milk production was recorded electronically for all cows. Composite a.m. and p.m. milk samples were collected during four consecutive milkings during the last 7 days of each period and analyzed for fat, protein, and lactose. Calculation of milk composition was weighted according to the a.m. and p.m. milk production. Body weight was recorded immediately after a.m. milking for 2 days one week prior to initiation of the trial and the last 2 days of each period.

Fecal samples were collected daily at the a.m. feeding during the last 6 days of each period to indirectly estimate total tract nutrient digestibility. Fecal samples were composited by period prior to chemical analyses, dried for 48 hours (60ºC), ground through a 1-mm Wiley mill screen, and analyzed for DM, CP, NDF, starch, and P for determination of total tract digestibility. Indigestible NDF (120-hour in vitro incubation) was used as the internal marker and total tract digestibility of DM, CP, NDF, starch and P were calculated.

Ruminal evacuations were performed the last day of each period on the 4 fistulated cows 2 hours prior to feeding to determine total ruminal volume and mass of the digesta. A representative sample of ruminal contents was collected at that time and frozen at -20ºC until further analysis. The ruminal content samples were subsequently thawed and dried at 60ºC for 3 days and ground through a 1-mm Wiley mill screen. Samples were analyzed for DM, NDF, starch and indigestible NDF (at 120 hours) and ruminal pool sizes were calculated by multiplying the digesta DM weight by the concentration of each component. Ruminal turnover rate was calculated.

Fractional rate of digestion and potential extent of NDF digestion of each silage were measured using the in situ bag technique. Silage samples were oven dried (60ºC) and ground though a Wiley mill (2-mm screen). In situ bags were removed from the rumen, rinsed, dried at 60ºC and weighed.

Table 3. Lactational performance as influenced by forage source.

	Forage sorghum				
Item	Normal	bmr-6[1]	bmr-18	Corn silage	SE
DMI					
lb/d	51.0	55.4	51.5	53.5	1.1
% of BW	3.67	3.79	3.65	3.81	0.19
NDF Intake					
lb/d	22.9^{ab}	19.8^{bc}	21.8^{ab}	19.8^{bc}	0.4
% of BW	1.62^{ab}	1.43^{bc}	1.53^{ab}	1.42^{bc}	0.06
Milk, lb/d	68.2^{b}	75.0^{a}	70.8ab	74.4^{a}	1.6
Milk Fat					
%	3.57^{b}	3.89^{a}	3.77^{ab}	3.88^{a}	0.21
lb/d	2.44^{b}	2.95^{a}	2.68^{ab}	2.90^{a}	0.11
Milk Protein					
%	2.89	2.89	2.98	2.97	0.14
lb/d	2.00	2.18	2.11	2.20	0.08
Lactose					
%	4.84	4.88	4.90	4.78	0.34
lb/d	3.37	3.70	3.48	3.56	0.17
4% FCM, lb/d	64.0^{b}	74.1^{a}	68.6^{ab}	73.3^{a}	2.3
FCM/DMI lb/lb	1.25	1.37	1.35	1.38	0.09
BW, lb	1399	1406	1410	1408	16
BW change, lb/28 d	-3.1	2.2	8.4	9.7	5.2

^{a,b}Means within a row with different superscripts differ (P<0.10)
[1]Brown midrib.

Table 4. In situ NDF digestion kinetics of the experimental silages.

Item	Forage sorghum Normal	bmr-6[1]	bmr-18	Corn silage	SE
Lag, h	0	0	0	0	0
K_d, /h[1]	0.023^{b}	0.037^{a}	0.034^{a}	0.036^{a}	0.003
PED, %[2]	70.4^{b}	76.4^{a}	73.1^{ab}	79.0^{a}	1.5
48-h NDFD, %[3]	56.4^{b}	62.4^{a}	61.0^{a}	59.1^{a}	1.9
r^2	0.95	0.95	0.94	0.92	

^{ab}Means within a row with unlike superscripts differ (P < 0.05).
[1]Fractional rate of NDF digestion (/h).
[2]Potential extent of NDF digestion at 96 h of in situ fermentation (%).
[3]In situ NDF digestion at 48 h of fermentation (%).

Table 5. Apparent total tract nutrient digestibility and ruminal turnover.

Item	Forage sorghum Normal	bmr-6[1]	bmr-18	Corn silage	SE
Digestibility, %					
DM	52.5^{b}	62.9^{a}	69.1^{a}	60.9^{a}	2.5
CP	51.3	59.9	59.2	51.4	4.5
NDF	40.8^{c}	54.4^{a}	47.9^{b}	54.1^{a}	1.8
Starch	85.7^{b}	82.3^{b}	79.7^{b}	91.7^{a}	1.5
Phosphorus	49.4^{b}	64.6^{a}	40.9^{b}	33.2^{c}	4.4
Turnover, %/h					
DM	3.18	3.90	3.33	2.96	0.90
NDF	2.93	3.21	2.33	2.10	0.75
Starch	49.0^{b}	51.6^{b}	59.7^{b}	83.3^{a}	1.5
Indigestible NDF	2.20	1.90	1.80	2.00	1.00

^{ab} Means within a row with unlike superscripts differ (P < 0.10).

Contents were analyzed for NDF at eac0h time point. Kinetics of NDF digestion and apparent extent of ruminal NDF digestion were calculated.

Results

The chemical composition of experimental silages is presented in Table 1. The conventional sorghum silage contained more lignin (measured as acid-detergent lignin or permanganate lignin) than the bmr-6 or bmr-18 sorghum hybrids. The ADF and NDF content of the conventional forage sorghum was greater than the bmr-6 or bmr-18 sorghum hybrids. The corn silage used in this study had lower NDF and permanganate lignin content, but higher CP, than the forage sorghum hybrids evaluated.

All four TMR were similar in DM, CP and calculated RUP content. The diets primarily differed in lignin, ADF, NDF and starch content which reflected the treatment silage in each diet.

Daily DMI (pounds/day) differed among cows fed the various sorghum and corn hybrids (Table 3). Those cows consuming bmr-6 sorghum had greater DMI than those consuming bmr-18 sorghum. There was no difference between the bmr-18 and the conventional sorghum, nor was there a difference among corn silage and any of the forage sorghums. When DMI was expressed as a percentage of BW, there was no significant difference among any treatments, although numerically DMI was highest for cows fed corn silage and bmr-6 sorghum and least for those fed normal sorghum.

Consumption of NDF was greater for the conventional and bmr-18 sorghum compared with corn or bmr-6 sorghum (Table 3) on both a % of BW basis and pounds per day consumed. Given that consumption of NDF was similar, or slightly less for bmr sorghum versus conventional sorghum, the positive milk production responses observed in the present study are likely due to differences in lignin content and NDF digestibility of the silages.

Milk production and milk fat were significantly different among diets (Table 3). The bmr-6 sorghum and corn silage had similar milk production, conventional sorghum was lowest, and the bmr-18 was intermediate. A similar trend was observed for milk fat production. There were no effects of diet on milk protein or lactose production. Production of 4% FCM followed the same trend as milk production and milk fat concentration. Cows fed bmr-6 sorghum and corn silage had greater FCM production than cows fed the conventional sorghum, with bmr-18 being intermediate. All bmr sorghum and the corn silage diet resulted in greater gross efficiency of FCM production (FCM/DMI) compared with the conventional sorghum. Diet had no effect on BW or change in BW during each 28-d period.

The fractional rate of NDF digestion measured in situ was greater for the bmr-6 sorghum, bmr-18 sorghum, and corn silage compared with the conventional sorghum (Table 4). The potential extent of ruminal NDF digestion was significantly lower for conventional sorghum versus the bmr-6 or corn silage; bmr-18 was intermediate. The NDF digestion at 48-hours

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was significantly less for the conventional sorghum than the other forages.

Total tract digestibility of NDF for corn and bmr-6 sorghum was greater than for bmr-18 sorghum which was greater than conventional sorghum (Table 5). Total tract starch digestibility was greater for cows fed the corn silage diet than the other diets which reflected the greater starch content of the corn silage and presumably greater starch digestibility. Digestibility of DM was least for the conventional sorghum diet. Interestingly, the bmr-18 sorghum was intermediate between conventional and bmr-6 sorghum for total tract NDF digestibility. Apparent P digestibility was greatest for BMR-6 and least for corn silage. In the present study, urinary and milk P were not accounted for so P retention could not be measured. However, the range in P digestibility does indicate that there may be opportunity to select bmr and conventional sorghum hybrids that would have an advantage relative to improved P digestibility.

Turnover of DM, NDF and indigestible NDF were unaffected by diet (Table 7). However, turnover of starch was greater for the corn silage diet than for any of the sorghum diets. This difference in starch turnover can be attributed to the greater starch content of corn silage compared with the sorghum hybrids.

In conclusion, lignin is the primary chemical factor limiting cell wall digestibility. The bmr forage sorghum hybrids both contained less lignin than the conventional sorghum and the corn hybrid. The bmr-6 sorghum outperformed the conventional sorghum hybrid with the bmr-18 sorghum being intermediate in most cases.

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[1]Rick Grant, professor and Extension dairy specialist; Amanda Oliver, graduate student, Lincoln; Jerry O'Rear, Garrison Townsend, Hereford, TX.

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